QUARTERLY PROGRESS REPORT
TO 31 MARCH 1990

PHASE III CONTINUATION

Continuing Data Analysis of 1987 Data Sets in Government Fiscal Year 1990

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1 INTRODUCTION

This report documents project progress to the end of March 1990. After a review of project aims during this year, we include a description of work undertaken and achievements under each open task. We review progress against scope of work and highlight any changes in project plans that have been made. The next quarter is previewed briefly. Finally, a list of issued deliverables and reports is appended.

2 AIMS

As outlined in the Scope of Work (issued in January 1990), our aims for this Fiscal Year were:

First, to provide a coherent set of data from each of the primary instruments, for the region of best co-location from the May 19th to 24th 1987 exercise.

Second, we proposed to derive a quantitative transfer function between the underice surface, as seen by sonar and the above ice surface, seen by AMMR and AOL, for example. This was to be achieved via SAR, which maps the surface as Sidescan does the underice surface. The question we wished to answer is: "What information about the ice surface beneath the water can be provided by remote sensing from above?" A subsidiary question is: "How reliable is this information?"

Finally, it was proposed that SAIC/Raleigh should use the available Upward-looking Sonar data (GFY 1989 deliverable) to continue to study the underice environment.

3 WORK COMPLETED BY 31st MARCH 1990

Three tasks were open during the period up to March 31st 1990. Tasks 1, 2 and 3 are discussed briefly below.

3.1 Task 1 Technical Liaison

Work under Task 1 has been ongoing throughout the past few months. Task 1 spans the whole year but no specific milestones were set. SAIC has issued supplementary deliverables associated with this task and intends to continue to do this.

3.1.1 Project Management

Considerable effort was expended early in the contract by SAIC/Cambridge to optimise the Statement of Work in order to determine the most efficient ways of satisfying all client requirements.

3.1.2 Analysis of Upward-looking Sonar data

An analysis of the underice environment was undertaken and a report prepared on this work. Called: "THE AUTOCORRELATION FUNCTION AND POWER SPECTRUM OF THE UNDERSIDE OF ARCTIC SEA ICE", the report was issued to ONR (three copies) as a supplementary deliverable, in March 1990. The analysis described is seen as a precursory analysis to that planned for SAIC/Raleigh in Task 6.

The 'away from the pole' Upward-looking Sonar data set, collected between 19th and 21st May 1987 was split into 35, 50km sections. These were sub-divided into 2km lengths and analyses of autocorrelation function and of power spectral density carried out for each. Results were averaged for each 50km section.

Analysing the autocorrelation function indicated that the underside of the ice is a 'rough' surface, with the fractal roughness measured by the Lipschitz exponent, α, of between 0.5 and 0.8. It was found that the autocorrelation function at small lags was unreliable, being affected by the beamwidth of the sonar.
For each section, the Lipschitz exponent was calculated using Mandlebrot's relation, from the power spectral density of the ice underside. Results agreed well with those obtained from the autocorrelation function analysis. The effect of the instrument's beamwidth is also seen at wavelengths less than 10m. Interestingly, it appears that the fractal roughness of the underice surface in Fram Strait is greater than to the north of

Greenland, even though the physical roughness of Fram strait ice (measured by r.m.s. ice draught) is lower in Fram Strait.

3.1.3 Technical Liaison

Continuing technical liaison between SAIC/Cambridge, Dr Wadhams and Dr Comiso has been concerned with planning work effort for open and later tasks. This is discussed further in Section 4 below.

3.2 Task 2 Data Map

Task 2 was required to confirm the region of best co-location of data sets during the exercise. The task was completed in January 1990, with the drafting of a map and overlays, outlining the extent and quality of data collected by the major instruments between 19th and 24th May. This was on schedule. However, a wait for security clearance delayed the issuance of the task deliverable until March.

The map and overlays are located by lining up their left hand edges. It was clear that the 20th May provided the best co-location over a significant length of submarine track, whilst two short lengths of co-location were seen on the 21st May. Using the Data Map it was clear that good quality Upward-looking Sonar and Sidescan data overlapped with SAR imagery for roughly 110km, whereas SAR and AOL overlapped for roughly 135km and Sidescan and SAR for 150km. All four data sets overlapped for roughly 65km (During GFY 1989, AOL and Upward-looking Sonar data were compared for 60km of this overlap, whilst all data sets were studied for a short 10km section).

After obtaining permission from UK MoD to issue the deliverable with a security classification of 'UK CONFIDENTIAL', SAIC sent fifteen copies of the Data Map to ONR during March 1990.

3.3 Task 3 Co-located Data Set / Sidescan Analysis

Task 3 was begun at the end of January 1990 and is due for completion at the end of April. Necessary revisions to the planned task work effort have put back completion, as have equipment problems with some of digitising effort. SAIC now

estimates completion in early June. However, this will not hold up Task 4, which has begun on schedule.

Task 3 was originally conceived as an opportunity to deliver a Data Pack containing all major data sets for the chosen region of best co-location, including an underice ice type 'map' and corresponding 'map' of SAR features for comparison. At the end of March 1990 Task 3 was still open. A brief review of progress is given below.

3.3.1 Task 3 Progress

Concern arose during February and March over the level of effort required by NASA staff during this phase of the project. SAIC clarified its position in this regard and concentrated Task 3 effort on in-house analysis of submarine data. It was understood that NASA personnel would take a more prominent role in the project during Task 5.

SAIC/Cambridge has acquired all relevant AMMR and AOL data, courtesy of NASA and has generated a SAR image of the region of best co-location with submarine track marked. This image is now being processed to add as overlays of AMMR footprints and AOL track, as a Data Pack product.

The main effort during February and March was ice type classification using Sidescan images, validated using Upward-looking Sonar. It was hoped that ice classification could be completed by early April, in order that it could be available to Dr Comiso for discussion at the SMM/I algorithm workshop. Thus, work on the Data Pack (other than the underice ice type map) was suspended.

The classification chosen was basically:
RR: Linear Ridge
MM: Clear Multiyear Floe
FF: Clear Firstyear Floe
L1: Lead
WW: Lead (Weakest Return)
UU: Unclassified Area

Any regions not delineated as one of the above are classified as 'Matrix', which is defined as 'hummocky with non-linear ridging'.

In order to obtain unambiguous statistical results, features that crossed the edge of the Sidescan swath were labelled with an 'e' for edge, so that these could be left out of some analyses if required. Every identified feature was assigned a unique identifier, so that feature-by-feature matching would be facilitated.

This task was completed in February and March saw us digitising this ice type map, which is intended as a major part of the Task 3 Deliverable. The level of difficulty and thus the time taken to do this, were greater than anticipated and we had some failures of equipment. However, the work was completed in March. The length of the Submarine/SAR co-location was reduced to 74 Sidescan images (119km) because of a lack of unambiguous tie points at the western end of the overlap. Following basic digitisation, the digital data were corrected and tied to the SAR image, using 50 clear tie points. We now have a digital ice type map that is as closely tied to the SAR image (and thus position) as is possible.

In March, we issued a report to ONR (three copies) on the classification and validation of ice types, called "THE CLASSIFICATION OF SIDESCAN SONAR IMAGERY FOR ICE TYPES". This was undertaken by hand using 90 images (approximately 150km of Submarine data). The main findings of the report are outlined below.

Upward-looking Sonar data were used to identify errors in classifying ice types on Sidescan Sonar imagery. Features could either be assigned to the wrong type (for the exercise these were defined as Type A errors), or the ice types clearly seen on the Upward-looking Sonar record were not identified using Sidescan (Type B errors).

The identification of Ridges and Multiyear ice floes was found to be particulary good, with only 3% and 13% mis-identified, respectively. The identification of Firstyear ice floes was less good, with only 34% correct (of a small sample of 31 validated floes) as was that of dark Leads (53% correct). Regarding Type B errors, many ridges clearly seen on the Upward-looking Sonar record were missed on the Sidescan image and many Multiyear floes were classified as Matrix using Sidescan.

It was concluded that the combination of both sonars has enabled an unequivocal classification of sea ice type to be made (along the centre of the Sidescan swath) and that the nature of errors further from the centre has been determined. This analysis provides the baseline for later work in transferring ice type information to the upper surface of the ice.

3.3.2 Summary

Task 3 effort on the generation of a Data Pack was suspended to allow us to concentrate on the Sonar-derived ice type map. This is now ready and related analysis work is ongoing. Further analysis will lead to reports and papers and will be considered as Task 1 effort. Presently (late April), work on the Data Pack has restarted and we anticipate that the product will be complete by late May or early June.

3.4 Task 4 Two-dimensional Ice Type Transfer

Task 4 was begun in February 1990 (at a low level) and is due for completion at the end of July. Task 4 effort is on schedule and has not been held up by delays in Task 3 work. Now, in April, Task 4 is our main open Task, running concurrently with Task 3 work on the Data Pack.

Task 4 sets out to tie the underice classification from Task 3 to the co-located SAR imagery by classifying the SAR, forming a map for the area covered by the Sidescan and overlaying the two maps. Areal statistics will be compared, determining the success in identifying confirmed ice types on the SAR and providing the link between confirmed ice regimes and AOL and AMMR data.

During February, a SAR classification scheme was devised which was not influenced unduly by our underice experience. The classification scheme was outlined in our February Progress Telemail and is essentially the following:

A: Very dark return, tending to have some linearity
B: Dark grey to black return, seen along the edges of A
   or replacing A in narrow, linear features
C: Light grey regions with some texture
D: Light lineations within Class C

E: Non-linear, floe-shaped regions with mottled mid-to-dark grey return
F: Bright, narrow linear features
G: SAR 'Matrix' (not necessarily equivalent to Sidescan Matrix)

As before, features crossing the edge of the Sidescan swath are called edge features (eg. AE, BE etc.). A class of unclassifiable features is not required, since the image quality is uniform across the swath. Also, note that the F class on SAR is not necessarily related to the FF or FE of Sidescan, which are Firstyear ice.

4 SUMMARY OF WORK ONGOING AT 31st MARCH 1990

4.1 Task 1

Technical liaison continues. This includes discussion of the precise nature of Task 3 and 4 deliverables. Also, exactly how we can deliver Task 5 successfully is being considered. Clearly, as the project evolves and Task 3 and 4 output is defined, the effort required during Task 5 will be seen to change. SAIC intends to take a pragmatic and flexible approach in order to make most efficient use of available time and resources. For example, recent discussion between SAIC, Dr Wadhams and Dr Comiso has resulted in an outline plan for Task 5 which will be communicated for comment in our next monthly progress telemail.

Also continuing is our analysis of results from the classification of the underice environment, which will lead to supplementary reports and a draft paper.

4.2 Task 3

During March and April we extracted key statistical information from the 119km of digital ice type data set and disseminated early results to Drs Wadhams and Comiso. Table 1 shows area statistics for this data set, by ice type. Note that Table 1 shows areas of features wholly within the swath, edge features and total areas.

Type	No.	Total Area $/10^6 m^2$	%	Mean $/10^3 m^2$	Median $/10^3 m^2$	St. Dev. $/10^3 m^2$
rr	1285	9.86	12.9	7.67	5.88	6.35
re	93	1.34	1.8	14.44	11.03	13.33
r	1378	11.20	14.7			
mm	589	10.64	14.0	18.06	9.76	24.34
me	222	12.01	15.8	54.09	27.48	68.90
m	811	22.65	29.7			
uu	4	0.02	0.03	4.82	3.70	4.04
ue	29	0.83	1.09	28.50	17.50	28.63
u	33	0.85	1.11			
ll	12	0.16	0.20	13.00	8.59	10.38
le	25	1.27	1.67	50.76	36.83	59.79
l	37	1.42	1.87			
ff	41	0.37	0.49	9.09	7.01	10.24
fe	26	1.01	1.32	38.74	22.32	39.43
f	67	1.38	1.81			
ww	53	0.45	0.59	8.52	4.73	10.99
we	18	0.39	0.51	21.64	10.83	32.03
w	71	0.84	1.10			
Mat.	-	37.81	49.65	-	-	-

Table 1. Areal statistics by feature type

Example identifiers:
rr: Ridge entirely within swath.
re: Ridge crossing swath edge.
r: All ridges.
mm: Multiyear ice.
uu: Unclassified.
ll: Lead L1.
ff: First year ice.
ww: Lead L2.

49.65% of the total area that is classified by default as Matrix. It is likely that there is no valid way to split this region into other ice types. We cannot know how the Matrix is made-up. The study area is clearly not a simple mix of clearly defined floes, ridges and leads. Of the area not comprising Matrix, the area of clear Multiyear floes (29.7% of the total) is twice that of clear linear ridges (14.7%). Firstyear and Lead fractions are only 1.81% and 2.97% (L+W), respectively.

Presently we are analysing further the floe, ridge and lead data within this unique ice type record and intend to prepare a paper on the results during the next quarter.

Since these validated ice type data sets are the first to be generated for a heavily ridged high Arctic region in late winter, they will provide a valuable resource for comparison with other remotely sensed data, such as AMMR and for validation of SMM/I algorithms.

Also for Task 3, we are continuing effort towards the completion of a suitable Data Pack for dissemination (subject to security clearance).

4.3 Task 4

During April we completed the classification of the 119km long (700m wide) SAR strip, which matches the Sidescan record and are presently digitising the SAR to form a map of the surface, as seen by SAR. As soon as this has been completed, work will begin to provide comparative statistics of SAR and Sonar ice types and to undertake a feature-by-feature comparison, as described in the Scope of Work.

4.4 Preparation for Task 6

Last September, the Upward-looking Sonar data (1989 deliverable) were issued by SAIC/Cambridge via ARE. During the last quarter these data were sent by ARE to ONR. The data are required by SAIC/Raleigh for Task 6 and SAIC/Raleigh have been in touch with ONR concerning their dissemination. Furthermore, SAIC/Cambridge is liaising with SAIC/Raleigh in order to expedite the use of the data.

5 PROJECT DELIVERABLES

5.1 Task 2: February 1990

DATA MAP Task 2 Deliverable

6 SUPPLEMENTARY DELIVERABLES

6.1 Task 1: March 1990

THE AUTOCORRELATION FUNCTION AND POWER SPECTRUM OF THE UNDERSIDE OF ARCTIC SEA ICE

6.2 Task 3: March 1990

THE CLASSIFICATION OF SIDESCAN SONAR IMAGERY FOR ICE TYPES

7 ACKNOWLEDGEMENTS

This report was prepared by SAIC/Cambridge (C B Sear) and is issued to ONR (fifteen copies) through SAIC MTG Management, San Diego.